Name ____

Hardy-Weinberg Practice

To estimate the frequency of alleles in a population in genetic equilibrium, we can use the Hardy-Weinberg equation:

$$p + q = 1$$
$$p^2 + 2pq + q^2 = 1$$

According to this equation:

p = the frequency of the dominant allele (represented here by *A*) ALLELES
q = the frequency of the recessive allele (represented here by *a*)

p^2 = frequency of *AA* (homozygous dominant) GENOTYPES
$2pq$ = frequency of *Aa* (heterozygous)
q^2 = frequency of *aa* (homozygous recessive)

You may be asked

- What are the frequencies of the two alleles?
- What are the frequencies of each genotype?

Where do we start?

1. No matter what frequency you are asked to determine in the end, it is typically helpful to start by calculating q^2 (unless given q directly)
    - We know that all the individuals with the recessive phenotype must be homozygous recessive (q^2)
        - Note: We cannot begin by calculating the value of p because some of the dominant individuals are homozygous (p^2) but others are heterozygous (2pq)
2. Once we know q^2, we can take its square root to calculate q
    - Remember, this is the frequency of the **recessive allele**
3. Next you can calculate p since p + q = 1.
    - Remember, this is the frequency of the **dominant allele**
4. From here you can plug in your values for p and/or q to calculate either
    - p^2 (frequency of **homozygous dominant genotype**)
    - 2pq (frequency of **heterozygous genotype**)

Tips:

- Double check your math
    - Do the frequencies add up to 100 percent?
- Pay attention to what the question is asking!
    - Allele frequency vs genotype frequency
    - Frequency in terms of decimal vs percent vs # of individuals

Name ____

Let's Practice:

1. You have sampled a population in which "A" is dominant over "a" and 360 out of 1000 individuals express the recessive phenotype. Determine the following frequencies, assuming the population is in Hardy-Weinberg equilibrium. Be sure to show your work.

   - What is the frequency of the "aa" genotype? q^2

360/1000 = 0.36 = 36%

   - What is the frequency of the "a" allele? q

√.36 = 0.6 = 60%

   - What is the frequency of the "A" allele? p

1 – 0.6 = 0.4 = 40% 60 + 40 = 100

   - What is the frequency of the genotype "AA"? p^2

$0.4^2 = 0.16 = 16\%$

   - What is the frequency of the genotype "Aa"? 2pq

2 (0.4) (0.6) = 0.48 = 48% 36 + 16 + 48 = 100

2. You have sampled a population in which "A" is dominant over "a" and 320 out of 500 individuals express the recessive phenotype. Determine the following frequencies, assuming the population is in Hardy-Weinberg equilibrium. Be sure to show your work.
   - What is the frequency of each of the following alleles?

q ○a √.64 = 0.8 = 80%

p ○A 1 – 0.8 = 0.2 = 20% 80

+ 20 = 100

   - What is the frequency of each of the following genotypes?

START HERE! q^2 ○aa 320/500 = 0.64 = 64%

p^2 ○AA $0.2^2 = 0.04 = 4\%$

2pq

Name ____

○ Aa 2 (0.2) (0.8) = 0.32 = 32% 64 + 4 + 32 = 100

3. In snapdragons, there are two alleles for flower color, red flower color (R) and white flower color (r). The heterozygotes have pink flowers. In a particular population of snapdragons, 81% of the flowers are red.

- What is the frequency of the red flower color allele in this population of snapdragons? p

  $p^2 = 0.81$ $\sqrt{.81} = 0.9$

- What is the frequency of the white flower color allele in this population of snapdragons? q

  $1 - 0.9 = 0.1$

- What percentage of snapdragons in this population will exhibit white flowers? q^2

$0.1^2 = 0.01 = 1\%$

- What percentage of snapdragons in this population will exhibit pink flowers? $2pq$

$2\,(0.9)\,(0.1) = 0.18 = 18\%$

4. Twenty people decide to start a new population, totally isolated from anyone else. Two of the individuals are heterozygous for a recessive allele, which in homozygotes causes cystic fibrosis. Assuming this population is in Hardy-Weinberg equilibrium, what fraction (expressed as a decimal) of people in this new population will have cystic fibrosis?

20 people = 40 alleles
2 alleles are recessive
$2/40 = 0.05 = q$
$q^2 = 0.05^2 = 0.0025$ (or $25/10{,}000 = 0.25\%$)

Name ____

5. In a population of mice, long hair (h) is recessive and short hair (H) is dominant. The population of the mice is 100, and there are 9 mice with long hair.

   - How many of the mice have short hair?

100 – 9 = 91 mice

   - What percentage of the alleles for hair length in this population are the long hair (h) allele? q

$9/100 = 0.09 = q^2$ $q = \sqrt{.09} = 0.3 = 30\%$

   - What percentage of the alleles for hair length in this population are the short hair (H) allele? p

1 – 0.3 = 0.7 = 70%

   - How many of the mice are homozygous for the short-hair allele? p^2

$0.7^2 = 0.49$ 0.49 x 100 mice = 49 mice

   - How many of the mice are heterozygous for the hair allele? 2pq

2 (0.7) (0.3) = 0.42 0.42 x 100 mice = 42 mice

6. In humans, unattached earlobes are dominant, and attached earlobes are recessive. In China, it is reported that 64% of the population exhibit unattached earlobes.

   - What percentage of the Chinese population exhibit attached earlobes?

100 – 64 = 36%

   - What is the frequency of the recessive (attached earlobe) allele in the Chinese population? q

$q^2 = 0.36$ $q = \sqrt{0.36} = 0.6$

   - What is the frequency of the dominant (unattached earlobe) allele in the Chinese population? p

1 – 0.6 = 0.4

   - What percentage of the Chinese population are homozygous for the dominant allele (unattached earlobe)? p^2

$0.4^2 = 0.16 = 16\%$

   - What percentage of the Chinese population are heterozygous for the earlobe allele? 2pq

Name ____

2 (0.4) (0.6) = 0.48 = 48%

7. A population of acacia trees is 16 percent short (which is a, recessive) and 84 percent tall (which is A, dominant). Determine the frequencies of each allele AND each genotype, assuming the population is in Hardy-Weinberg equilibrium. Be sure to show your work.

aa = 0.16 = 16%

a = √.16 = .4 = 40%

A = 1 – 0.4 = 0.6 = 60%

AA = 0.6^2 = 0.36 = 36%

Aa = 2 (0.4) (0.6) = 0.48 = 48%

8. A population has 700 individuals, 85 of genotype AA, 320 of genotype Aa, and 295 of genotype aa. Assuming the population is in Hardy-Weinberg equilibrium, what are the frequencies of alleles A and a?

First find aa
295/700 = 0.42

a = √.42 = 0.65

A = 1 – 0.65 = 0.35

Name ____

9. The frequency of allele a is 0.45 for a population in Hardy-Weinberg equilibrium. What are the expected frequencies of genotypes AA, Aa, and aa?

$q = 0.45$
$p = 1 – 0.45 = 0.55$

$AA = p^2 = 0.55^2 = 0.30 = 30\%$

$Aa = 2pq = 2 (0.45) (0.55) = 0.50 = 50\%$

$aa = q^2 = 0.45^2 = 0.20 = 20\%$

10. In a population with two alleles, B and b, the allele frequency of b is 0.4. What would be the frequency of heterozygotes if the population is in Hardy-Weinberg equilibrium?

$q = 0.4$
$p = 1 – 0.4 = 0.6$

$2pq = 2 (0,4) (0.6) = 0.48 = 48\%$

Name ____

Using Hardy-Weinberg to Determine if a Population is Evolving

1. Determine the total number of alleles in the population
   - There are **TWO** alleles per individual
2. Determine how many of those alleles are dominant vs recessive
   - Each homozygous dominant individual has **TWO** dominant alleles
   - Each homozygous recessive individual has **TWO** recessive alleles
   - Each heterozygous individual has **ONE** of **EACH** allele
3. Determine the frequency of each allele
4. Calculate the expected frequencies of each genotype for a nonevolving population (based on the Hardy-Weinberg equation)
5. Multiply the calculated frequencies by the total number of individuals in the population
6. Compare the observed and expected results
   - Remember, the Hardy-Weinberg principle describes a population that is NOT evolving
   - So if the observed frequencies do not match the expected frequencies, then the population is NOT in Hardy-Weinberg equilibrium and thus may be evolving at that locus

Example:
A locus that affects susceptibility to a degenerative brain disease has two alleles, V and v. In a population, 16 people have genotype VV, 92 have genotype Vv, and 12 have genotype vv. Is this population evolving? Explain.

- Total number of individuals = 120
- Total number of alleles = 120 x 2 = 240

- Number of dominant alleles = (16 x 2) + 92 = 124
- Number of recessive alleles = (12 x 2) + 92 = 116

- Frequency of v allele = 116/240 = 0.48
- Frequency of V allele = 124/240 = 0.52 (or 1 – 0.48 = 0.52)

- Expected frequency for vv = $0.48^2 = 0.23$
- Expected frequency for VV = $0.52^2 = 0.27$
- Expected frequency for Vv = 2 (0.52) (0.48) = 0.50

- Expected number of vv individuals = 0.23 x 120 = 28
- Expected number of VV individuals = 0.27 x 120 =32
- Expected number of Vv individuals = 0.5 x 120 = 60

- Do the observed results match the expected results? No (less homozygotes and more heterozygotes than expected)
- Is the population in Hardy-Weinberg? no
- Is the population evolving at this locus? yes